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TRANSLATION

FUEL ADDITIVES, AN EFFECTIVE MEANS FOR RAISING THE MOTOR POWER OF POWER INSTALLATIONS

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FUEL ADDITIVES, AN EFFECTIVE MEANS FOR RAISING THE MOTOR POWER OF POWER INSTALLATIONS

P. P. Botkin

The majority of petroleum products in our country is produced from petroleums from the eastern regions. The petroleum yield in those regions in 1960 was 9.4 times greater than in 1950 and 2.6 times larger than in 1955.

Eastern-region petroleums are distinguished by the presence of sulfur, the percentage of which reaches 1.5-4.2 in petroleum, 2.1-4.2 in fuel oil, and 0.9-2.5 in diesel fuel. The sulfur content in motor fuel which is a mixture of fuel oil and kerosene-gas oil fractions amounts to 1.2 to 3%. As a result of this the provisions of GOST [All-Union Soviet State Standard] for petroleum products of sulfur-containing petroleums permit the following sulfur content: in diesel fuel, up to 1.0% (GOST 305-58); in solar oil, up to 1.9% (GOST 1666-51); and motor fuel, up to 2.5% (GOST 1667-51).

It is well known that the use of sulfur-containing fuels complicates the operating conditions of power, especially diesel, installations because of increased scaling, wear, and corrosion of components of the boilers, diesels, and fuel systems.

The attack of the sulfur-containing compounds in fuel comes in both a liquid and gaseous phase. If in the liquid phase, only a few sulfur compounds like mercaptans, elemental sulfur, and hydrogen sulfide are considered aggressive; while in the gaseous phase all sulfur compounds are aggressive, since they form SO_2 and SO_3.

The following may be noted in regard to the negative effect of sulfur-containing compounds of fuel on the components of diesels.

The increased wear of the fuel system occurs to a considerable degree as a result of the so-called dryness of sulfur-containing fuel, especially of diesel fuel, which does not form a durable lubricating film on the piston elements of the fuel pumps and jets. In operation this may lead to sticking of the pumps and of the jet needles. When the jet needles stick, blow-by of gases from the combustion chamber is possible and this leads to corrosion of the components.

Together with what has been indicated there is also possible in this case the action of aggressive sulfur-containing compounds in the liquid phase. All this leads to increased wear and disturbance of the tightness of the piston elements in the fuel system and is a primary cause of deterioration of the fuel combustion process and of increased scaling.

Increased wear in the cylinder-piston complex of the internal combustion engine is chiefly the result of

1) gas corrosion in the zone of highest temperatures where the condensation of moisture is impossible. The heavy growth of corrosion begins after the corroding surface has reached a temperature above 300° C. This corrosion is most possible under a stabilized engine work regime and principally in high-speed, thermically strained diesels.

2) acid corrosion in the low temperature zone where the condensation of moisture is possible and, consequently, the formation of sulfurous and especially sulfuric acid. In this the temperature change in the dew point, which is 80° to 115° higher for sulfur-containing fuels than the condensation point of pure water vapors corresponding to the partial pressure of the latter in the gases, is of great importance. Acid corrosion may take place in variable diesel work regimes in zones where the temperature is below the dew point.

3) abrasive wear which increases because the products of oxidation of sulfur depositing themselves in scale make the latter harder. For example, when the sulfur in the fuel increases from 0.1 to 1.5% the scale density grows by a factor of 16.

The heightened wear and corrosion sharply increase when the fuel is flooded with sea water.

In general, then, wear in the use of fuels containing much sulfur may be 1.5 to 3 times higher than in a low-sulfur fuel.

In order to depress the attacking action of sulfur compounds in fuel, diesel-engineering establishments have gone along with using wear and corrosion resistant materials and structural changes like the use of chrome plating of bushings and piston rings, inserts of heat resistant steel in areas of high temperature, improvement of separation and filtration of fuels, increasing the temperature of the cylinders by raising the temperature of the water coolant, etc.

The measures cannot, however, in full measure secure power maintenance in power installations when working on sulfur-containing fuel on the level of power resource characteristic of operation on low-sulfur fuel.

In this connection there appeared the necessity of using additives to fuels and oils which in the whole complex of measures taken might protect the components of power installations, especially diesel, from the attack of the sulfur-containing compounds in fuel in the liquid and gas phases. Different chemical compounds are generally called additives. These are organic and inorganic compounds added in small quantities to fuel or oil in order to improve their quality.

It is necessary to remember that the action of diesel fuel and oil additives is different in its local protective activity.

Oil additives decrease scale and varnish formation in the frictional parts of the motor since they inhibit oil oxidation and retard deposits and the products of contamination in the suspended state, and, by the same token, prevent their precipitation from the oil in the form of residue.

They also neutralize the aggressive sulfur-containing compounds in scale in low-temperature zones, usually before the first piston ring, i.e., they decrease abrasive wear as a result of acid corrosion. It is evident that additives cannot by any means improve the action of the fuel system , lower its wear, or essentially influence scale formation on the top of the piston and the diesel cylinder head.

In general, then, when correctly chosen, oil additives are very effective and they can reduce the wear in the piston-cylinder complex of diesels by 70% in operation on sulfur-containing fuel.

The effect of fuel additives is felt even in the liquid phase; and owing to that they can considerably improve the operation of the fuel system, decreasing its corrosion, wear, and scale formation. This property is especially important in the operation of

power installations (boiler and diesel) on sulfur-containing and heavy fuels. The presence of combustion-intensifying components in fuel additives favors more complete combustion of fuel, reducing the formation by the latter of scale in the combustion chamber area. The neutralizing components of the additives decrease the aggressive action of sulfur-containing compounds in the gaseous state, i.e., they decrease the wear from gas and acid corrosion and also decrease the abrasive properties of the deposits.

Additives to fuel can decrease component wear in the piston-cylinder complex of diesels up to 50%.

According to their purpose fuel additives can be divided in three basic groups: additives to diesel fuels, to boiler, and to gas turbine fuels.

In 1957 the Scientific Research Institute for the Processing of Petroleum and Gas and for the Production of Synthetic Liquid Fuel [hereafter abbreviated VNII NP] (laboratory of Prof. N. A. Butkov) together with specialists from the Ministry of the Navy and the Navy Central Scientific Research Institute created the first domestic multipurpose additives for sulfur-containing fuels, that is, for boiler fuel oils designated VNII NP-102; for diesel motor fuels, VNII NP-101; and for diesel fuel, VNII NP-111.

Table 1 gives the basic physico-chemical characteristics of these additives.

Domestic fuel additives do not contain ingredients that are difficult to find. For example, the initial raw material for producing diesel and motor fuel additives is gas oil obtained by catalytic cracking, metal naphthenates, tricresyl phosphate, nitrobenzene, orthodichlorobenzene, and lanolin. All these are products of domestic industry.

As the result of tests by the Navy Central Scientific Institute, the Central Disinfection Scientific Research Institute [TsNIDI], the Far-Eastern Steamship Line of the Navy Ministry, the Northwest River Steamship Line of the River Fleet Ministry of the Russian Federated Soviet Socialistic Republic, and by the October Railroad it has been ascertained that fuel additives are one of the effective means of raising the power potential of power installations.

Tests of the additive VNII NP-102 in ships' boiler installations and in locomotives when burning fuel oil with a content of sulfur up to 3.5% showed a decrease in the deposits on the heating surfaces by 35-60%. The nature of the deposits themselves changed and they became gummier and more easily removable from the heating surfaces. At the same time the jets became less clogged with coke.

The additive VNII NP-102 can also prevent the formation of deposits on the bottoms of fuel reservoirs and disperse the precipitates already formed during fuel storage. At present this additive is produced by the petroleum industry and is widely used on Navy Ministry vessels and in locomotives of the Railroad Ministry.

The additive VNII NP-101 was tested in stationary and vessel installations in diesels operating on motor fuel with sulfur contents of 0.88%, 1.5%, 1.74%, and 2.6% and coke contents of 1.5%, 3.4%, 5.8%, and 8.5%. The other physico-chemical characteristics of the fuel were in accord with the requirements of GOST [All-Union State Standard] 1667-51.

Table 2 shows the basic results of these tests.

The additive VNII NP-101 also proved to be effective even in use with sulfur-containing diesel fuels. In this case the wear in the piston-cylinder complex decreased by 30%.

In processing the oscillograms of the operating process of diesel 4Ch 17.5/24 no substantial change in the ignition lag of the fuel was determined when additives were used. The action of the additive was most clearly marked in the phase of combustion completion; this is indicated by the increase of CO_2 in the exhaust gases and the decrease in fumes. When operating on motor fuel (sulfur 2.6%, coke 5.8%) without additive the fumes were 10-15% higher than with diesel fuel; with motor fuel with additive the fumes were equal to those with the diesel fuel (measurements made on a TsNIDI capnometer).

Testing the additive VNII NP-111 was conducted under stand and vessel conditions on diesel fuel with a sulfur content of 0.9%, 1.0%, and 1.2%, with the other physico-chemical characteristics according to GOST 305-58.

The basic results of these tests are shown in Table 2, from which it is evident that additive VNII NP-111 showed no decrease in piston ring wear under stand conditions and afforded a very small decrease in it under operating conditions.

In order to increase the efficiency of the additive an additional active component was added to it - barium naphthenate.

Table 2 shows the basic results of the tests on the improved additive.

In this respect it should be noted that when the temperature of the water coolant was 80-85° in diesel 1Ch 8.5/11 slight formation of varnish on the piston was observed and also partial burning of the first piston ring.

In diesels operating with the exiting water at a temperature of 50-55° no such phenomena were observed.

Motor and diesel fuel additives in an experimental injection series have been used for the last two years in the motorships of the Far-Eastern Line and have been accepted by the operators as a means for raising motor power, improving the operation of the fuel system and decreasing scale and wear.

The improvement in the operation of the fuel system by additives is a result of improving the lubricating properties of the fuels with the additives and neutralizing the sulfur-containing compounds in the liquid phase.

For example, when additive VNII NP-101 is used, the frictional coefficient of the motor fuel used in a given case as a lubricant decreases 10% and that of the diesel fuel by 40%.

Additives help neutralize the aggressive sulfur-containing compounds in the fuel.

Experiments have ascertained that by adding 1% of additive VNII NP-101 to sulfur-containing fuel containing 0.21% of mercaptans the quantity of these latter decreased to 0.005%.

The decrease in scaling, as has already been indicated, results from improving the thorough combustion of the fuel and also by changing the properties of the scale itself, which becomes looser and therefore can be partially removed by drainage. In addition, the individual components of the additives under definite conditions can intensify the combustion of the fuel.

Lowering of wear results from the decrease in the abrasive properties of the scale, as well as from neutralization of the aggressive sulfur-containing compounds in the liquid phase. When testing the abrasive properties on an MI friction machine it was ascertained that specimen wear in friction with scale produced with additiveless fuel amounted to 2.5μ and the scale produced with 0.2%

of additive (the optimum concentration under the conditions of the experiment) decreased wear to 0.5μ.

Neutralization of the aggressive sulfur-containing compounds may result from possible combination of the additive metal with the sulfur oxides, thus forming stable sulfates which do not dissociate under combustion chamber conditions. For example, $BaO + SO_3$ gives $BaSO_4$ (barium sulfate), a completely neutral salt. Copper and zinc may act in a similar manner.

In addition, the phosphorus of the combustion additive may in an oxide environment transform into phosphoric acid H_3PO_4 or its anhydride P_2O_5.

The latter compound can form a protective film of variable composition in the diesel cylinder preventing the formation of foci of corrosion.

An important aspect of the use of additives is the methods of introducing them into the fuel and the stability of the fuel mixtures in protracted storage. It must, unfortunately, be noted that here there are definite difficulties. The additives must be thoroughly mixed with the fuel. The most reliable method of mixing is simply repeated circulation. During protracted storage (longer than 30 days) the additives have a tendency to settle. To remove these drawbacks it is necessary to find mean of putting additives into the fuel right in the refineries at some stage or other of the manufacturing process in order to secure lasting stability of the mixture and uniform volumetric distribution of the additives in the fuel. The solution of this problem is the direct responsibility of the petroleum industry institutes.

The cost of the additives in the recommended concentrations

does not exceed 1.5% of the cost of the fuel and this is economically completely justified by the increase in the motor power by decreasing wear and in increasing the reliability of operation of power plants.

The following conclusions may be drawn on the basis of the research:

1) fuel additives are one of the effective means of increasing motor power and reliability of operation of power installations. By using fuel additives for diesels wear in the cylinder-piston system can be decreased to 50%.

2) in diesel power installations it is expedient to use fuel and oil additives. The optimum concentration of fuel additive in this case should be determined experimentally.

TABLE 1

Physico-chemical characteristics of additives to sulfur-containing fuels

Characteristic	VNIINP*-102	VNIINP-101	VNIINP-111
Specific gravity at 20°C	0.980	0.930	0.933
Kinematic viscosity at 50° C ccm		6.8	4.8
Flash point °C			
open crucible	65	—	—
closed crucible	—	132	130
Solidification temperature, °C	−10	−23	−20
Saponification number mgKOH/g	—	13	—
Ash content, %	—	1.18	0.20
Iodine number	18	—	—
Naphthalene content %	5	—	—
Sulfonaters, %	98	55	—
Water soluble acids and alkalis		lacking	
Active components	Naphthalene homologues	Cu, Ba, P	P, Zn, Cl
Concentration of additives in fuel, wt. %	0.2	0.3—0.5	0.7—0.8

*VNII NP = All-Union Scientific Research Insitute for the Processing of Petroleum and Gas and for the Production of Synthetic Liquid Fuel.

TABLE 2

Basic Results of Additive Tests

Diesel	Number of revolutions, rpm	Power, bhp	Average effective pressure, kg/cm²	Oil	Decrease in wear, % — Wheels: first	Decrease in wear, % — Wheels: all	Decrease in wear, % — Cylindrical bushings: upper zone	Decrease in wear, % — Cylindrical bushings: average	Decrease in scale formation	Work of fuel apparatus
VNII NP-101										
1Ch10.5/13	1500	10	5.34	D-11	37/70	(Radioactive isotope method)				
4Ch17.5/24	750	100	5.1	D-11	27	30	41	47	27	Decreasing wear by 35%
4Ch31/41	375	450	4.0	AK-15	—	12	—	60	Substantial decrease	Same by 26%
6DR 56/100	155	2400	4.8	AK-15	Not measured		46	50	Looser scale	Decreasing scale formation
6 DKR 45/74	185	1500	4.8	AK-10			44	43	40	
VNII NP-111										
2Ch10.5/13	1500	20	5.35	D-11	0	0	55	51	50	No changes noted
6Ch15/18	1500	150	4.73	DS-11	18	11	13	32	Looser scale	Scale formation decreased
6DR 34/57	300	1100	5.35	D-11	Not measured		50	60	Considerable decrease	Reliability increased Scale formation decreased
6DKR 57/80	225	4000	5.35	MS-20			46	51	Looser scale	No changes noted
VNII NP-111 (improved)										
1Ch8.5/11	1500	7	5.75	DS-11	40	52	57	57	Looser scale	No changes noted
2Ch10.5/13	1500	20	5.34	DS-11	20	29	49	12		
1Ch10.5/13	1500	10	5.34	DS-11	34	(Radioactive isotope method)				
6DR 34/57	300	1100	5.35	D-11	6	19	46	44	Decrease (visual)	Decreasing scale formation
6DKR 57/80	225	4000	5.35	MS-20	31	14	35	40	Not perceptible	No changes noted

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